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(54) **Wavelength tunable semiconductor laser light source**

Halbleiterlaser-Lichtquelle mit abstimmbarer Wellenlänge

Source de lumière à semi-conducteur à longueur d'onde accordable

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- **PATENT ABSTRACTS OF JAPAN vol. 15, no. 98 (E-1042), 8 March 1991 & JP 02 306679 A (KOMATSU LTD), 20 December 1990,**

[0024] In FIG. 8, "D" is the thickness of the interference filter 201, and "n" is the refractive index thereof.

[0025] The wavelength of each transmittance peak is given by the following formula:

$$k\lambda_k = 2nD \times \cos(\phi) \qquad (2)$$

where ϕ is the angle of the normal N to the interference filter 201 with the optical axis in the interference filter, and k is an integer.

[0026] When L is the length of the external resonator and m is an integer, like the case of an interference filter, the oscillation longitudinal mode of the external resonator is expressed as follows:

$$m\lambda_m = 2L \qquad (3)$$

[0027] Next, an example of characteristics of wavelength tunable LD light source, using an optical filter comprising a combination of a diffraction grating and an interference filter is illustrated in FIGS. 10A to 10E.

[0028] FIG. 10A shows a gain characteristics of LD, which generally has a gain in a wavelength range not less than 100 nm.

[0029] FIG. 10B shows a resonator mode corresponding to the formula (3), which are oscillation longitudinal modes.

[0030] Several modes are selected by using the filter characteristics of the diffraction grating shown in FIG. 10C, among the oscillation modes.

[0031] Then, a single mode is selected by using the filter characteristics of the interference filter shown in FIG. 10D. As a result, a single mode oscillation is obtained, as shown in FIG. 10E.

[0032] By changing each of the characteristics shown in FIGS. 10B, 10C, and 10D, that is, by changing L, θ, and ϕ suitably, it is possible to carry out wavelength scanning.

[0033] The relationship between the wavelength and L, θ, and ϕ is found on the basis of previous measurements. According to the relationship, the drive unit 3 having a combination of a motor, a rotary table, a directly linear-moving mechanism and the like realizes a state of particular values of L, θ, and ϕ, corresponding to the set wavelength.

[0034] The so-called WDM (Wavelength division multiplexing) of optical communication system which is recently focused on is one multiplexing several wavelengths with a difference of wavelengths of about 1 nm. For example, when the wavelengths difference is finely adjusted at a level of about 0.1 nm, wavelength accuracy having a level of about 0.01 nm which is taken a figure down in comparison with that of the wavelengths difference is required.

[0035] On the contrary, although the obtained set resolving power in the former art is a level of 0.001 nm, the set wavelength accuracy thereof is about a level of ±0.1 nm because of error factors, e.g., a backlash or a hysteresis on the mechanism, or set condition reproducibility including a fluctuation in temperature, a change with the passage of time or the like.

[0036] Therefore, in order to improve the set wavelength accuracy, it was required to prepare not only an external resonator type of wavelength tunable LD light source but also an expensive wavemeter, to measure the wavelength of the light source output by the wavemeter, and to correct the setting.

SUMMARY OF THE INVENTION

[0037] The present invention was developed in view of these problems.

[0038] An object of the invention is to provide a wavelength tunable LD light source which can assure a wavelength accuracy having a level of about ±0.01 nm.

[0039] That is, in accordance with one aspect of the present invention, as defined in Claim 1, the wavelength tunable semiconductor laser light source comprises; an external resonator type of semiconductor laser source unit; an optical filter for selecting an output beam of the external resonator type of semiconductor laser source unit in a single mode; a drive unit for changing wavelength of a transmitted beam or of a reflected beam, from the optical filter; a control unit for controlling the drive unit; an optical coupler for receiving the output beam of the external resonator type of semiconductor laser source unit as one of incident beams and for outputting it into two branches; a fiber grating for receiving an output beam from the optical coupler; a first etalon for receiving a reflected beam from the fiber grating through the optical coupler; a first measuring unit for etalon transmittance, for measuring a transmittance of the first etalon to transmit to the control unit; a second etalon for receiving the other of the two branched output beams of the optical coupler; and a second measuring unit for etalon transmittance, for measuring a transmittance of the second etalon to transmit to the control unit.

[0040] According to a wavelength tunable LD light source having such a construction, it is possible to set a wavelength optically while monitoring the output wavelength, by transmitting the transmittance of the first etalon and the transmittance of the second etalon, to the control unit and by adjusting the wavelength of a transmitted beam or of a reflected beam, from the optical filter of the external resonator type of semiconductor laser source unit.

[0041] Therefore, it is possible to prevent error factors on the mechanism from adverse effect to the set wavelength, and to assure a set wavelength accuracy having a level of about ±0.01 nm.

[0042] Preferably, the semiconductor laser light source further comprises; a first beam splitting device for receiving the reflected beam from the fiber grating

wavelength-transmittance of the interference filter, as an optical filter;

FIGS. 10A to 10E are views for explaining of the principle of oscillation mode selection of the wavelength tunable LD light source having a combination of a diffraction grating and an interference filter, as an optical filter, in which FIG. 10A is a view showing a characteristics of wavelength-LD gain, FIG. 10B is a view showing a characteristics of wavelength-resonator mode, FIG. 10C is a view showing a characteristics of wavelength-grating reflectivity, FIG. 10D is a view showing a characteristics of wavelength-interference filter transmittance, and FIG. 10E is a view showing a characteristics of wavelength-oscillation mode; and

FIG. 11 is a view showing a construction of the wavelength tunable LD light source according to a prior art.

PREFERRED EMBODIMENT OF THE INVENTION

[0050] An embodiment of the semiconductor laser (LD) light source tunable in wavelength according to the invention will be explained with reference to FIGS. 1 to 3, as follows.

[0051] FIG. 1 is a block diagram for showing a construction of the wavelength tunable LD light source according to an embodiment of the invention. In this figure, the same elements and the like as corresponding ones in FIG. 11 have the same reference numerals, and the detailed explanation for them will be omitted.

[0052] In FIG. 1, the reference numeral 5 denotes an optical coupler, 6 denotes a fiber grating, 7 and 10 are first and second beam splitting devices, respectively, 8 and 11 are first and second etalons, respectively, and 9 and 12 are first and second measuring units for etalon transmittance, respectively.

[0053] The optical coupler 5 receives an output beam from the external resonator type of LD light source unit 1 as one input and produces branched two outputs. One of the two output beams branched at the optical coupler 5 is inputted into the fiber grating 6. The transmitted light of the fiber grating 6 is used as the output beam of the wavelength tunable LD light source.

[0054] The reflected light from the fiber grating 6 is inputted into the optical coupler 5 again and produces branched two outputs into the side of the external resonator type of LD light source unit 1. One of the branched two output lights is inputted into the first beam splitting device 7.

[0055] The first beam splitting device 7 splits the inputted light into two outputs. One of the two output lights splitted at the first beam splitting device 7 transmits the first etalon 8 and thereafter inputs into the first measuring unit 9 for the first etalon transmittance. The other of the two output lights splitted at the first beam splitting device 7 inputs into the first measuring unit 9 for etalon transmittance directly.

[0056] In the first measuring unit 9 for the first etalon transmittance, the transmitted light through the first etalon 8 and the direct inputted light from the first beam splitting device 7 are measured, and the ratio of intensities, i.e., the transmittance of the first etalon 8, is found. The result is sent to the control unit 4.

[0057] The other of the two output beams branched at the optical coupler 5, from the external resonator type of LD light source unit 1 is input to the second beam splitting device 10.

[0058] The second beam splitting device 10 outputs the input beam into two branches. One of the two output lights splitted at the second beam splitting device 10 transmits the second etalon 11 and thereafter inputs into the second measuring unit 12 for the second etalon transmittance. The other of output beams from the second beam splitting device 10 is input to the second measuring unit 12 for etalon transmittance directly.

[0059] In the second measuring unit 12 for etalon transmittance, the transmitted beam through the second etalon 11 and the direct beam input from the second beam splitting device 10 are measured, and the intensity ratio, that is, transmittance of the second etalon 11, is determined and transmitted to the control unit 4.

[0060] The control unit 4 gives an instruction to the drive unit 3 so that the value of transmittance data from the first and second measuring units 9 and 12 for etalon transmittance correspond to the wavelength origin and the position of set wavelength, on the basis of the relationship between etalon transmittance and wavelength which were measured by using a precise wavemeter and stored in advance.

[0061] Next, a method for detecting the wavelength origin will be explained with reference to FIG. 2.

[0062] The fiber grating 6 is a fiber type of optical filter. The index of refraction n_f of the fiber core thereof periodically changes at a period Λ. The wavelength λ_{fg} of reflectivity peak is given by the following formula:

$$\lambda_{fg} = 2\, n_f \Lambda \qquad (4)$$

where the wavelength λ_{fg} is set out of the range of output wavelength of the Wavelength tunable LD light source and therefore exerts no effect on the output level.

[0063] Although the full width at half maximum (hereinafter, it may be referred to FWHM) of the reflection curve of the fiber grating shown in FIG. 2A depends on the change of the index of refraction nf and the length of the changing region, it will be assumed to be 2 nm in the following explanation.

[0064] Next, the characteristics of transmittance of the first etalon 8 is shown in FIG. 2B.

[0065] The etalon is an interference filter and FIGS. 8 and 9 and the above-described formula (2) can be referred for it.

[0066] The spacings between modes are called the

perature change of about 0 to 40 °C is a level of ±0.2 nm and in consideration of it, FSR1 of the first etalon (etalon 1) 8 is set to be wide enough, it is not considered to detect an adjacent mode.

[0088] As described above, according to use of the fiber grating 6, the first etalon 8 and the second etalon 11, it is possible to carry out an optical wavelength setting while monitoring the output wavelength and to prevent the effect of error factors on the mechanism on the set wavelength.

[0089] That is, for example, a design described above enables assurance of a set wavelength accuracy having a level of about ±0.01 nm.

[0090] As described above, the wavelength tunable LD light source according to the embodiment of the invention is provided with an optical coupler, a fiber grating, first and second beam splitting devices, first second etalons, and first and second measuring units for etalon transmittance. Therefore, according to the embodiment, it is possible to obtain an advantageous effect of improvement of a wavelength accuracy having a level of about ±0.01 nm, without measuring to ascertain the wavelength of the light source output by a wavemeter every setting.

[0091] In the above embodiment, although each of the first and second measuring units compares the light intensity of transmitted beam through each etalon with the other of output beams from each beam splitting device to measure the transmittance of each etalon, in order to perform wavelength setting more precisely, such a comparing means is not essential to accomplish the object of the invention.

[0092] FIG. 4 is a block diagram for showing a construction of the wavelength tunable LD light source according to another embodiment of the invention. In FIG. 4, the same elements and the like as corresponding ones in FIG. 1 have the same reference numerals, and the detailed explanation for them will be omitted.

[0093] In FIG. 4, the reference numeral 15 denotes a first beam splitting device for receiving an output beam from the external resonator type of LD light source unit 1 as one input and produces branched two outputs. One of the two output beams branched at the first beam splitting device 15 is used as the output beam of the wavelength tunable LD light source and the other is inputted into a second beam splitting device 17. The second beam splitting device 17 splits the inputted light into two outputs. One of the two output lights splitted at the second beam splitting device 17 transmits an etalon 18 and thereafter inputs into a measuring unit 19 for the etalon transmittance. The other of the two output lights splitted at the second beam splitting device 17 inputs into the measuring unit 19 for etalon transmittance directly.

[0094] In the measuring unit 19 for the etalon transmittance, the transmitted light through the etalon 18 and the direct inputted light from the second beam splitting device 17 are measured, and the ratio of intensities, i. e., the transmittance of the etalon 18, is found. The result is sent to the control unit 4.

[0095] The reference numeral 23 denotes a wavemeter for specifying a wavelength of the output beam of the semiconductor laser source unit 1 with an accuracy in a free spectral range of the etalon 18, on the basis of the output beam of the semiconductor laser source unit 1. The specified wavelength by the wavemeter 23 is given to the control unit 4. The specification of wavelength can be carried out also by using information from the drive unit 3, with respect to wavelength to be set.

[0096] The control unit 4 gives an instruction to the drive unit 3 so that the data relating the specified wavelength from the wavemeter 23 and the transmittance data from the measuring unit 19 for etalon transmittance correspond to the wavelength origin and the position of wavelength to be set, on the basis of the relationship between etalon transmittance and wavelength which were measured and stored in advance.

[0097] As described above, according to a wavelength tunable LD light source having such a construction, it is possible to set a wavelength optically while monitoring the output wavelength, and therefore to prevent error factors on the mechanism from adverse effect to the set wavelength, and to assure a set wavelength accuracy having a level of about ±0.01 nm.

Claims

1. A semiconductor laser light source tunable in wavelength, comprising;

    an external resonator type of semiconductor laser source unit (1);
    an optical filter (2) for selecting an output beam of the external resonator type of semiconductor laser source unit in a single mode;
    a drive unit (3) for changing wavelength of a transmitted beam or of a reflected beam, from the optical filter;
    a control unit (4) for controlling the drive unit;

    characterised in that the laser light source further comprises,

    an optical coupler (5) for receiving the output beam of the external resonator type of semiconductor laser source unit as one of incident beams and for outputting it into two branches;
    a fiber grating (6) for receiving one of the two branched output beams from the optical coupler;
    a first etalon (8) for receiving a reflected beam from the fiber grating through the optical coupler;
    a first measuring unit (9) for etalon transmittance, for measuring a transmittance of the first etalon to transmit to the control unit;

serlichtquelle ferner umfaßt:

einen optischen Koppler (5), um den Ausgangsstrahl der Halbleiterlaserquelleneinheit vom externen Resonatortyp als einen einfallenden Strahl zu empfangen und um diesen in zwei Zweigen auszugeben;
ein Fasergitter (6), um einen der zwei verzweigten Ausgangsstrahle von dem optischen Koppler zu empfangen;
einen ersten Etalon (8), um einen reflektierten Strahl von dem Fasergitter über den optischen Koppler zu empfangen;
eine erste Meßeinheit(9) für Etalontransmittanz, um eine Transmittanz des ersten Etalons zu messen und zu der Steuereinheit zu übertragen;
einen zweiten Etalon (11), um den anderen der zwei verzweigten Ausgangsstrahle des optischen Kopplers zu empfangen; und
eine zweite Meßeinheit (12) für Etalontransmittanz, um eine Transmittanz des zweiten Etalons zu messen und zu der Steuereinheit zu übertragen.

2. Wellenlängenabstimmbare Halbleiterlaserlichtquelle nach Anspruch 1, ferner umfassend:

eine erste Strahlaufteileinrichtung, um den reflektierten Strahl von dem Fasergitter über den optischen Koppler zu empfangen und um diesen in zwei Zweigen auszugeben, von denen einer zu dem ersten Etalon ausgegeben wird, wobei der andere zu der ersten Meßeinheit für Etalontransmittanz ausgegeben wird, so daß die erste Meßeinheit für Etalontransmittanz eine Lichtintensität des durch den ersten Etalon transmittierten Strahles mit dem anderen der von der ersten Strahlaufteileinrichtung ausgegebenen Strahle vergleicht, um die Transmittanz des ersten Etalons zu messen; und
eine zweite Strahlaufteileinrichtung, um den anderen der zwei verzweigten Ausgangsstrahle des optischen Kopplers zu empfangen, und um diesen als zwei Zweige auszugeben, von welchen einer zu dem zweiten Etalon ausgegeben wird, wobei der andere zu der zweiten Meßeinheit für Etalontransmittanz ausgegeben wird, so daß die zweite Meßeinheit für Etalontransmittanz eine Lichtintensität des durch den zweiten Etalon transmittierten Strahles mit dem anderen der von der zweiten Strahlaufteileinrichtung ausgegebenen Strahle vergleicht, um die Transmittanz des zweiten Etalons zu messen.

3. Wellenlängenabstimmbare Halbleiterlaserlichtquelle nach Anspruch 1, bei welcher der erste Etalon einen Interferenzfilter umfaßt.

4. Wellenlängenabstimmbare Halbleiterlaserlichtquelle nach Anspruch 1, bei welcher der erste Etalon über einen freien Spektralbereich verfügt, welcher breiter ist als eine volle Breite beim Halbmaximum einer Reflektionskurve des Fasergitters.

5. Wellenlängenabstimmbare Halbleiterlaserlichtquelle nach Anspruch 1, bei welcher eine Fläche des ersten Etalons eine Reflektivität von nicht weniger als 90 % aufweist.

6. Wellenlängenabstimmbare Halbleiterlaserlichtquelle, umfassend:

eine Halbleiterlaserquelleneinheit (1) vom externen Resonatortyp;
einen optischen Filter (2), um einen Ausgangsstrahl der Halbleiterlaserlichtquelle vom externen Resonatortyp bei einem Einzelmodus auszuwählen;
eine Antriebseinheit (3), um die Wellenlänge eines von dem optischen Filter transmittierten Strahles oder eines von dem optischen Filter reflektierten Strahles zu verändern; und
eine Steuereinheit (4), um die Antriebseinheit zu steuern;

dadurch gekennzeichet, daß die Laserlichtquelle ferner umfaßt:

eine erste Strahlaufteileinrichtung (15), um den Ausgangsstrahl von der Halbleiterlaserquelleneinheit vom externen Resonatortyp als einen einfallenden Strahl zu empfangen, und um diesen als zwei Zweige auszugeben;
einen Etalon (18), um einen der Ausgangsstrahle von der ersten Strahlaufteileinrichtung zu empfangen;
eine Meßeinheit (19) für Etalontransmittanz, um eine Transmittanz des Etalons zu messen und diese an die Steuereinheit zu übertragen; und
einen Wellenmeter (23), um eine Wellenlänge des Ausgangsstrahles der Halbleiterlaserquelleneinheit bei einer Genauigkeit in einem freien Spektralbereich des Etalons anzugeben, und zwar auf der Basis des Ausgangsstrahles der Halbleiterlaserquelleneinheit oder auf der Basis von Informationen von der Antriebseinheit, um die angegebene Wellenlänge zu der Steuereinheit auszugeben.

7. Wellenlängenabstimmbare Halbleiterlaserlichtquelle nach Anspruch 6, ferner umfassend:
eine zweite Strahlaufteileinrichtung, um den einen der Ausgangsstrahle von der ersten Strahl-

une unité de commande (4) pour commander l'unité d'entraînement ; caractérisé en ce que la source de lumière laser comprend de plus un premier dispositif de séparation de faisceau (15) pour recevoir le faisceau de sortie de l'unité de source laser à semi-conducteur du type à résonateur externe en tant que l'un des faisceaux incidents et pour le diviser en deux branches ;

un étalon (18) pour recevoir l'un des faisceaux de sortie provenant du premier dispositif de séparation de faisceau ;

une unité de mesure (19) pour la transmittance d'étalon, destinée à mesurer une transmittance de l'étalon en vue de la transmettre vers l'unité de commande ; et

un onde-mètre (23) pour spécifier une longueur d'onde du faisceau de sortie de l'unité de source laser à semi-conducteur avec une précision dans un domaine spectral libre de l'étalon, sur la base du faisceau de sortie de l'unité de source laser à semi-conducteur ou sur la base d'informations provenant de l'unité d'entraînement, afin d'appliquer la longueur d'onde spécifiée à l'unité de commande.

7. Source de lumière laser à semi-conducteur accordable en longueur d'onde selon la revendication 6, comprenant de plus ;

un deuxième dispositif de séparation de faisceau pour recevoir l'un des faisceaux de sortie provenant du premier dispositif de séparation de faisceau et pour le diviser en deux branches, dont l'une est appliquée à l'étalon et l'autre est appliquée à l'unité de mesure pour la transmittance de l'étalon, de sorte que l'unité de mesure pour la transmittance d'étalon compare une intensité lumineuse du faisceau transmis à travers l'étalon avec celle de l'autre des faisceaux de sortie provenant du deuxième dispositif de séparation de faisceau en vue de mesurer la transmittance de l'étalon.

FIG. 2A

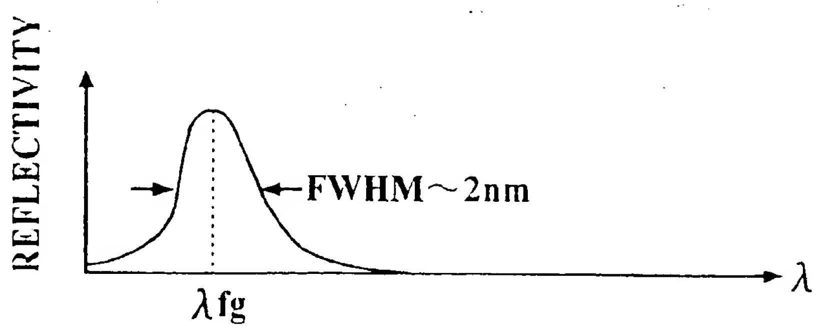

FIG. 2B

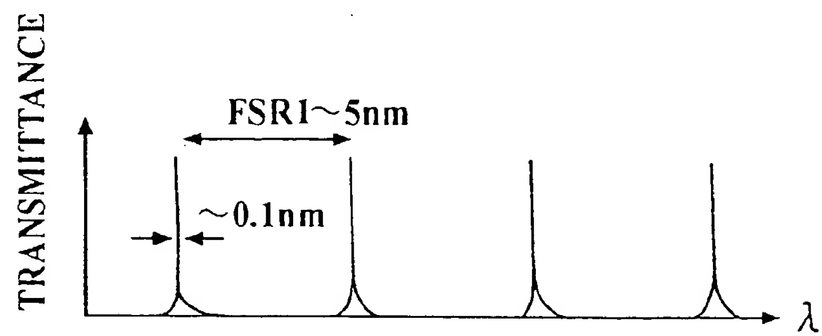

FIG. 2C

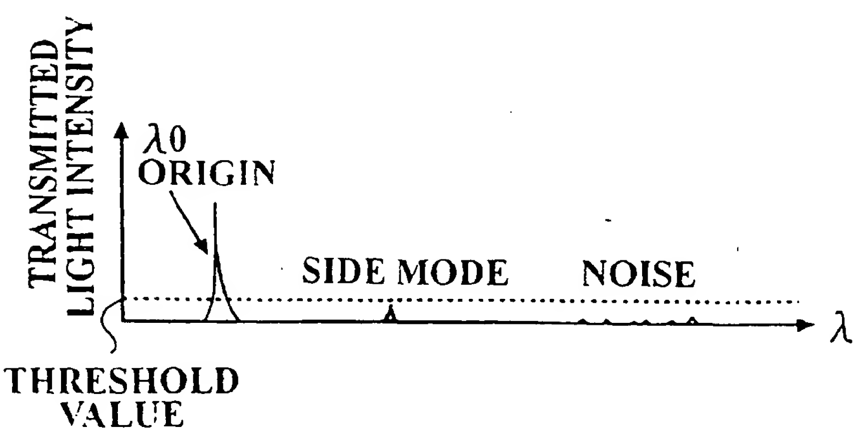

FIG.4

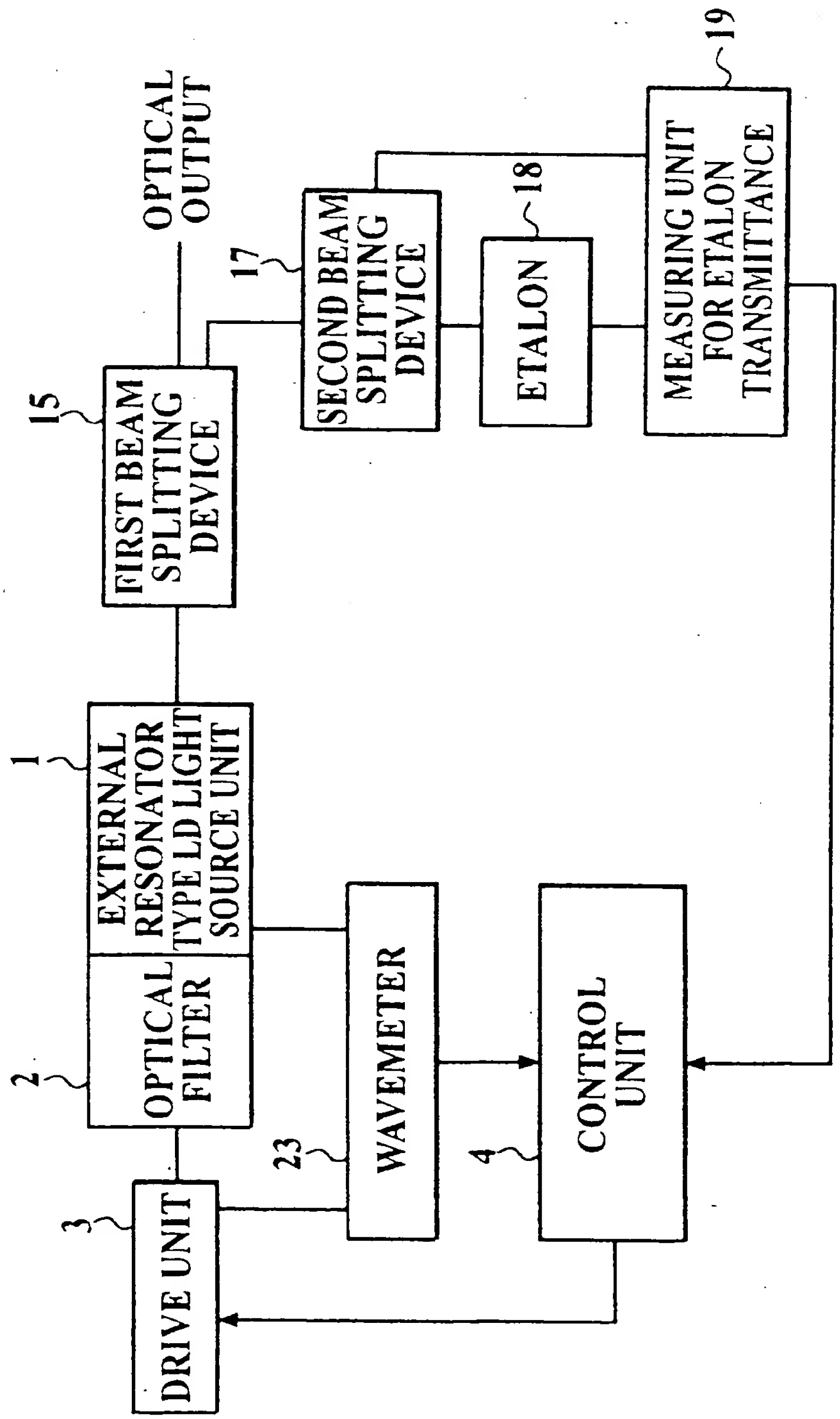
OPTICAL OUTPUT
1
EXTERNAL RESONATOR TYPE LD LIGHT SOURCE UNIT
2
OPTICAL FILTER
3
DRIVE UNIT
15
FIRST BEAM SPLITTING DEVICE
17
SECOND BEAM SPLITTING DEVICE
18
ETALON
19
MEASURING UNIT FOR ETALON TRANSMITTANCE
23
WAVEMETER
4
CONTROL UNIT

FIG.6

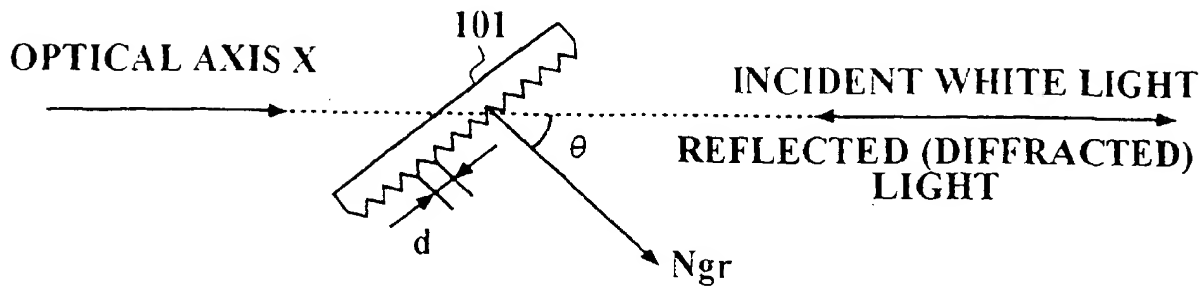
101
OPTICAL AXIS X
INCIDENT WHITE LIGHT
θ
REFLECTED (DIFFRACTED) LIGHT
d
Ngr

FIG.7

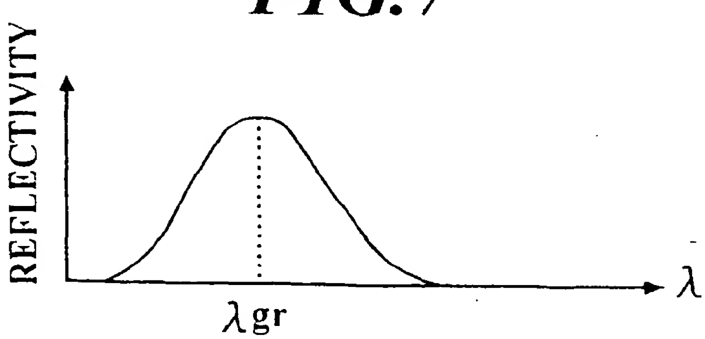
REFLECTIVITY
λ
λgr

FIG.10A

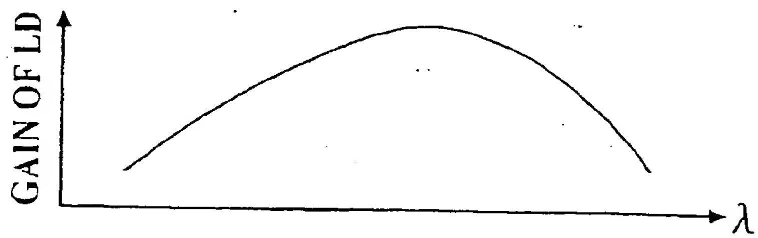

FIG.10B

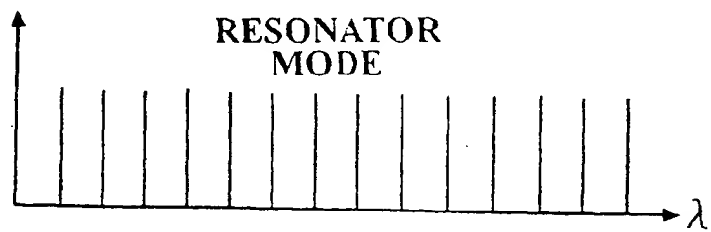

FIG.10C

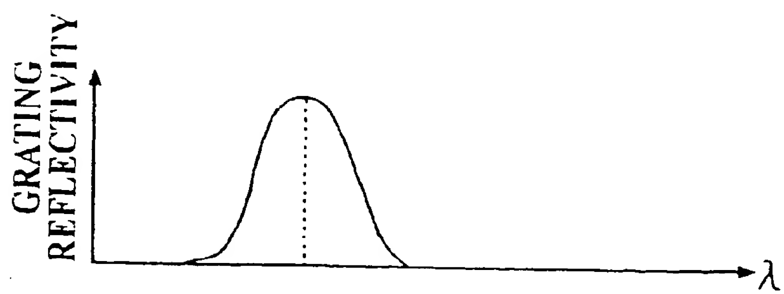

FIG.10D

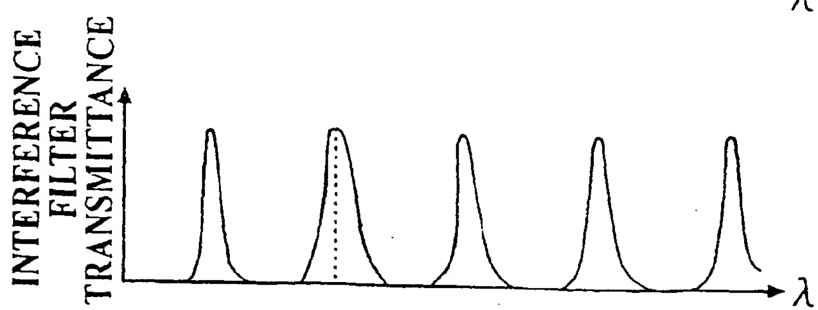

FIG.10E